

# **Agricultural Land Elasticities in the United States and Brazil**

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## **Abstract**

The elasticity of aggregate supply is one key to understanding the degree to which policy-induced increases in demand for biofuel feedstocks or agricultural CO<sub>2</sub> offsets will result in higher prices or expanded supply. In this paper we report land supply elasticities for the United States and Brazil estimated directly from the observed changes in cropland and estimated changes in expected returns. The resulting aggregate implied land-use elasticities with respect to price are quite inelastic in the United States and more elastic in Brazil (0.007-0.029 and 0.382-0.895, respectively). However, with pasture land included in Brazil, implied elasticities become much less inelastic (0.007-0.245).

**Keywords:** acreage elasticity, Brazil, indirect land-use change, land-use elasticities.

## **Background**

The extent to which land will be converted from forests and pasture into crops has become one of the most important issues facing U.S. agriculture. The concern is that increased demand for biofuels will lead to deforestation, thereby negating part or all of the CO<sub>2</sub> reduction associated with replacing fossil fuels (Searchinger et al. 2009; Fargione et al. 2008). More recently, proposals to allow U.S. agriculture to participate in a cap-and-trade program limiting greenhouse gas emissions by providing offsets from tree planting (Brown et al. 2010) have raised fears that agricultural production will shift overseas, thereby increasing deforestation rates. Estimates of the impact of biofuels and offset programs all hinge on how much land will be brought into production in response to policy-induced price increases.

Estimating the acreage response to price has a long history in agricultural economics. Houck and Ryan (1972) studied the acreage response of corn from 1948 to 1970. They examined three different groups of variables affecting planted corn acreage: government policy, market influence, and other supply determinants. The price of corn from the previous crop year was used as one of the variables representing the market influence group. Over the years, additional variables have also been used to explain the change in agricultural land use. These variables include output price relative to a variable input price index (Lee and Helmberger 1985; Tweeten and Quance 1969), expected price (Gardner 1976), acreage value (Bridges and Tenkorang 2009), and expected net returns (Chavas and Holt 1990; Davison and Crowder 1991). Davison and Crowder argue that using expected net returns to explain acreage decisions is better than using price alone because net returns account for changes in input prices.

Although there is a large body of literature examining farmers' acreage response, most studies focus primarily on specific crops or specific regions. To our knowledge, few studies

report the acreage elasticity at the country level. One example is the acreage elasticity with respect to price in the United States by Tweeten and Quance (1969). The aggregate acreage elasticity is crucial for understanding how a change in crop returns will affect deforestation rates because use of crop-specific acreage elasticities will infer high conversion rates.

Aggregate crop supply elasticities are used by two of the models used by the Environmental Protection Agency (EPA) and the California Air Resources Board (CARB) to determine the amount of indirect land use associated with biofuels regulations. GTAP, the model used by CARB, uses a U.S. cropland supply elasticity to calibrate its elasticity of land transformation (Ahmed, Hertel, and Lubowski 2008). The U.S. and Brazilian components of the FAPRI (Food and Agricultural Policy Research Institute) modeling system, used by EPA, also use aggregate crop supply elasticities. The U.S. model (FAPRI 2004) uses an aggregate elasticity to allow decoupled payments to influence total agricultural acreage. The Brazil model uses an aggregate elasticity as a first step in determining crop-specific regional acreage responses to price changes.

We calculate aggregate land-use elasticities directly by dividing the observed change in aggregate acreage by an estimate of the change in expected net returns. For the United States, expected net returns include expected returns from those government programs that affect farmers' acreage response (Chavas and Holt 1990). Expected net returns also account for changes in costs over time. To convert the elasticity of land use with respect to expected net returns into a price elasticity, we multiply by the elasticity of expected net returns with respect to price (Lin et al. 2000). The next section provides more details about the calculations.

## **Methodology**

In agriculture, the elasticity of land use with respect to expected net returns is the percentage change in aggregate land use due to a 1% change in expected net returns. Farmers' decisions of

what crops and how many acres to plant are assumed to be based on their expected net returns prior to the planting time. If net farm returns are expected to increase, more land will be converted to agricultural use (Feng and Babcock 2010).

Table 1 shows the composition of cropland in the United States over the past 15 years. The eight major crops included account for almost 95% of the total cropland used. Table 2 shows cropland for Brazil where five major crops account for almost 90% of the total land used. These crops represent a great proportion of land use. Hence their contraction or expansion should capture changes in aggregate land use in both countries.

To obtain a measure of expected net returns, we consider farmers' expectations prior to planting time. In forming expectations we assume that farmers use all information available to them at that time. Thus, expected net returns can be calculated as

$$(1) \quad \text{Expected net returns} = \text{Expected revenue} - \text{Expected cost}$$

$$(2) \quad \text{Expected revenue} = \text{Expected crop price} * \text{Expected yield} \\ + \text{Expected marketing loan payments.}$$

Expected marketing loan payments are included only for the United States. Other farm programs are assumed not to have a first-order impact on farmers' planting decisions (Babcock 2007; Hart and Babcock 2005).

Prior to planting season, decisions about what and how much to plant have to be made without knowing actual crop prices or actual crop yields. This means that farmers have to make their planting decisions based, at least in part, on expected prices and costs. To capture farmers'

expectations about price during planting time, we use pre-planting-time quotes of harvest-time futures. This assumption follows numerous other studies in which it is assumed that farmers use futures prices to form their price expectations (Dhuyvetter 2004; Gardner 1976). We also assume that Brazilian farmers rely on futures prices. While there are futures markets for several commodities in Brazil, adequate liquidity only exists for coffee, soybeans and cattle.<sup>1</sup> Thus, we assume that Brazilian farmers use U.S. futures prices to form their price expectations. Table 3 shows the futures contracts, the month in which price expectations are formed, and the month in which harvest is valued for the eight U.S. crops and the five Brazilian crops. Note that in Brazil, the expected price for the first-crop corn crop differs from the expected price for the second-crop corn crop to reflect differences in planting time.

The timing convention in Table 3 can be understood through the following example: to obtain the expected price of corn during the planting time in 2008 in the United States, we take the average price of the December 08 futures contract during business days in January 2008. For Brazilian corn during the planting time 2008, the expected price is calculated by averaging the March 09 futures contract during September 2008.

Since a sugarcane futures contract is not available in the United States, we obtain the expected price of sugarcane by using the price relationship between sugarcane and sugar. This approach is justified because sugar is highly correlated with sugarcane, and sugar also has futures contracts readily available in the United States. To calculate this price relationship, we use the price of sugar from the futures contract (Symbol: SB) traded at the Intercontinental Exchange (ICE) and the actual price of sugarcane from FAPRI. The futures price is retrieved during September of the previous year (T-1) for the current year (T) March contract. The annual

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<sup>1</sup> The BM&FBOVESPA market (<http://www.bmfbovespa.com.br/en-us/home.aspx?idioma=en-us>) carries futures for soybeans, corn, ethanol, sugar, coffee, and live cattle.

price relationship is calculated by dividing the price of sugarcane by the price of sugar. Finally, the price relationship is calculated by averaging the annual price relationship between 1996 and 2005. Multiplying this price relationship by the futures price of sugar yields the expected price of sugarcane.

The problem of using the harvest-time futures averaged during planting time as expected price is that it is not a perfect estimator of the actual price received by the farmer. Even if the futures price is an unbiased estimator of the harvest-time futures price, basis needs to be accounted for by translating futures prices to cash prices received by farmers. In the United States, the season average price (SAP) published by USDA's National Agricultural Statistics Service (NASS) is a widely used measure of the cash price received by farmers. To use the Chicago Board of Trade (CBOT) futures prices as an estimator of the SAP (for the U.S.), we need to account for any basis. Table 4 shows the basis between the futures contracts and the actual SAP. To calculate this basis, we assume that as futures get closer to maturity, the futures price converges to the cash price. Therefore, the harvest-time futures price averaged during the last month of the contract can provide an estimate of the cash price. This basis is calculated by subtracting the SAP from the harvest-time futures price during the last month of the contract. By subtracting this basis from the futures price, we should be able to obtain an expected SAP, which is an average of farmers' expected received price. Table 5 shows expected prices used in equation (2).

We also need to account for basis in Brazil. The basis for rice and that for cotton are calculated by subtracting the average domestic price from March futures contracts and taking the average of this difference over 1996-2008 for rice and over 1998-2008 for soybeans. The expected price for a Brazilian rice farmer is obtained by subtracting this basis from the pre-

planting quotes of harvest-time futures. Since the futures contracts are quoted in U.S. dollars, to convert these into Brazilian real, we employ the exchange rate during the same period as the futures. However, since there are no March futures for the Brazilian real and U.S. dollar, we use the exchange rates obtained from the February futures contract.

The basis for soybeans is calculated in a similar manner. However, our data source contains both U.S. and Brazilian prices of soybeans during 1998-2008. Therefore, we simply subtract the Brazilian domestic price from the U.S. price and take the average of this difference in order to get the basis. For sugarcane, since the expected price of sugarcane is calculated using the price relationship between the price of sugarcane in Brazil and the futures price of sugar in the United States, the basis is already included in the expected price and no additional basis needs to be applied. Finally, there is no systemic difference between the Brazilian domestic price of corn and the CBOT corn futures contract. Thus, we do not subtract any basis from corn futures contracts. Table 6 shows the basis for Brazil.

Table 7 shows the resulting expected harvest-time prices. These prices are assumed to capture farmers' expected prices during the planting season of each crop year. Although prices in Table 5 are in nominal terms and prices in Table 7 are in real terms (year 2000 is the base year), this does not create a problem for the final calculations because all expected net returns are normalized to year 2000 dollars.

#### *Marketing Loan Benefits*

Among the three major subsidy programs contained in farm bill legislation, the marketing loan program is the program that is most likely to alter a farmer's planting decision (Hart and Babcock 2005; Babcock 2007). Therefore, expected marketing loan payments are accounted for in the U.S. calculations. The details of the marketing loan program can be found in Babcock



(2007) and will not be restated here. Calculating expected payments farmers receive from the program requires the following four components: (i) loan rates, (ii) expected SAP, (iii) the loan deficiency payment (LDP) price gap, and (iv) price volatility.

Loan rates are obtained directly from the 1996, 2002, and 2006 farm bills and are shown in Table 8. At the planting time of each year, expected SAP is unknown. Hence, the estimated expected SAP obtained from the previous section is used as an approximation of the expected SAP.

The LDP price gap is obtained from a previous study (Hart and Babcock 2005). Price gaps for the major commodities are shown in Table 9. This gap accounts for intra-season price volatility that typically allows farmers to obtain payments even when the SAP indicates that no payments are forthcoming. The fourth column of Table 9 shows the LDP price gap as a percentage of the average planting time quote of the harvest-time futures contract shown in Table 5.

To calculate the price volatility, we follow Zhang's (2006) approach, which uses the implied volatility from options markets as an estimate of price volatility. Zhang calculates the implied volatility using at-the-money put option on futures. To be more precise, here we use the average of the implied volatility calculated from two at-the-money put options. The options on harvest-time futures are selected daily during the pre-planting months (as shown in Table 1). The implied volatility is calculated using the three-month treasury rate. This implied volatility is expected to be the volatility of the futures over the remaining life of the option, which is the time between planting and harvest. Therefore, this volatility is appropriate for our analysis. Table 10 shows the estimated implied volatility.

Finally, the estimated marketing loan benefits are calculated by randomly drawing prices using the estimated SAP as the mean (from Table 5) and the implied volatility as the volatility. For each draw, the marketing loan gain is calculated using the following formula:

$$(3) \quad \text{Expected benefits} = \max ( 0 , \text{Loan Rate} - (\text{estimated SAP} - \text{LDP price gap})^2).$$

We use the average of 20,000 draws for each commodity each year. Table 11 shows the expected marketing loan benefits perceived by the farmer as additional revenue during the pre-planting time.

#### *Expected Crop Yields*

To calculate expected crop yields for the United States, we use NASS yields. Expected yields are updated each year by fitting a linear trend to yields from 1980 up to the previous year. For example, to calculate the expected yield of corn for 1995, we use the actual yield between 1980 and 1994 to construct a trend and project the 1995 yield using this trend. Table 12 shows expected U.S. yields.

The expected yield in Brazil has to be estimated differently because our actual yield data for Brazil only goes back to 1995. For each region, we use the actual yield data between 1995 and 2009 to estimate the yield trend. Then, we apply this trend to project the expected yield for each year between 1995 and 2009. Expected yield in Brazil can be found in Table 13.

#### *Expected Costs*

We use actual variable production costs as our measure of expected costs. These data are taken from FAPRI. Costs for grains in Brazil were based on CONAB and calculated by ICONE,

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<sup>2</sup> The difference between the estimated SAP and the LDP price gap is the estimated posted county price received by the farmer when receiving the marketing loan gain. The LDP price gap is provided in Hart and Babcock 2005.

using a weighted average. For sugarcane costs we used a mix of sources, including IBGE, IDEA, and FNP Institute, and calculated by ICONE. Variable cost data are available in different units between the United States and Brazil. In the United States, variable costs are available in nominal dollars, whereas, in Brazil, they are available in year 2000 real dollars. Table 14 and Table 15 show the variable costs in the United States and Brazil, respectively. Variable costs explicitly show an increasing trend in both countries over time.

## **Results**

Plugging in expected crop prices, expected crop yields, marketing loan benefits, and expected costs into equations (1) and (2) gives us expected net returns by crops. The expected net returns at the country level are calculated by weighting the expected net returns<sup>3</sup> of each crop by its planting area. Figure 1 and Figure 2 show the aggregate land use and expected net returns in the United States and Brazil, respectively. Appendix A provides details of the total planting area and the weighted expected net returns. In the United States, expected net returns increased sharply from 2006 to 2009. At their peak in 2008, expected net returns were almost \$300/acre, more than double the average net returns in the past. During the same period, the area planted increased by 5 million acres, from 234 to 239 million acres. The sharp increase in the expected net returns stems from the large run-up in agricultural commodity prices resulting from a variety of factors, including increased ethanol production and global demand.

One estimate of the aggregate elasticity can be obtained by simply taking the percentage change in planted acreage after the run-up in expected net returns and dividing it by the percentage change in expected returns. An alternative is to estimate what acreage and returns

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<sup>3</sup> For the remainder of the paper, we use the expected net returns and the weighted expected net returns interchangeably.

would have been during 2007-09 had the run-up in expected net returns and acreage not occurred and then use these as the basis for calculating the elasticity. We do both.

Figure 3 shows what acreage and expected net returns would have been for 2007, 2008, and 2009 using a simple linear trend to project both. If the commodity boom during 2006-09 had not occurred, then Figure 3 provides one projection of what U.S. acreage and expected net returns would have been.

There is no set procedure for calculating elasticities directly, as we propose to do here. Using three-year averages of pre-boom years (2003 to 2005) and post-boom years (2007 to 2009), land use and expected net returns would smooth out variability in single-year acreage response. From Figure 1, average land use during 2003-05 is 236.8 million acres. The 2007-09 average is 237.5 million acres. Thus, the average acreage change is 0.3% (using the arc elasticity convention of basing percentage change on the average across the two periods). Average expected real net returns during the same period are \$129.86 and \$231.03 per acre respectively, which implies a 56.07% increase in expected net returns. Thus, the elasticity of the aggregate acreage crop is 0.005. This calculation and alternatives are shown in Table 16. If the elasticity is calculated using a base period of 2004-06 instead of 2003-05, then the acreage elasticity is about three times higher at 0.014. The base period of 2004-06 should provide us with the upper-bound estimate of elasticity since it contains the lowest area, hence, the largest area change, prior to the largest jump in returns in our data.

If we base calculations on changes relative to the simple projection of what expected net returns and acreage would have been had the run-up in agricultural commodity prices not occurred (as shown in Figure 3), then we get a higher implied elasticity of 0.029. These three

different approaches of calculating elasticity all indicate that over the time period examined, the aggregate response of U.S. crop acreage to increased returns is quite inelastic.

To convert the returns elasticity to a price elasticity we need to estimate the elasticity of expected net returns with respect to price. To do this, the change in expected net returns is estimated holding costs and expected yields constant and then increasing each crop price by 10%. The result is divided by 0.1 to obtain the percentage change in expected net returns with respect to a 1% change in price. The average of the two period elasticities is used.<sup>4</sup> For the United States, the impact on expected marketing loan gains was accounted for. From this calculation, the change in expected net returns resulting from a 1% increase in expected price ranges from 1.038% to 1.337%. The implied acreage price elasticity is then calculated by multiplying the acreage elasticity with the expected returns to price elasticity. As shown in Table 16, the values of the implied acreage elasticity with respect to expected price ranges from a low of 0.007 to a high of 0.029; hence, elasticities in the United States appear to be quite inelastic.

In Brazil, as shown in Figure 2, although land supply elasticities during the late 1990s and the beginning of the 21st century seem quite responsive to expected net returns, the land response in the more recent period demonstrates a much smaller increase. To determine the magnitude of this difference, we calculate elasticities during the early part of the decade beginning in 2000 as well as the later part of the decade.

First, we consider the five-year period of expected net returns between 1998 and 2002. This period is picked because it contains a massive land expansion and a dramatic increase in returns. However, Figure 2 shows that land expansion lagged increased returns by about two years. This perhaps reflects the time it took for new roads to be constructed and land to be cleared.

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<sup>4</sup> For example, for the period 2003-05 and 2007-09 (second column in Table 16. Elasticity of Land Use Table 16), the price elasticity is the average of the price elasticities between the period 2003-05 and 2007-09.

Therefore, to calculate the land change response to this change in returns during this period, we use two different periods of land use: (i) the contemporaneous period and (ii) the two-year lag period between 2000 and 2004. Furthermore, to avoid the large variation between years, we smooth out variability in a single-year response by using a three-year average of land use and expected net returns. As a result, the change in expected net returns is calculated using the difference between the average of 1997-99 and 2001-03 where the change in land use is calculated using the difference between the same period for the contemporaneous case and using the difference between the average of 1999-2001 and 2003-05 for the two-year lag case.

Table 17 shows returns elasticities using contemporaneous and two-year lag land use. For the contemporaneous and the two-year lag cases, the arc change in expected net returns is 49.8% and the arc changes in land use are 16.4% and 22.1%, which implies land elasticities of 0.33 and 0.44, respectively. With a 2.01% increase in expected returns resulting from a 1% increase in expected prices, the implied land-use elasticities with respect to expected price are 0.664 and 0.895 for the contemporaneous and the two-year lag, respectively. As one would expect, the elasticity of land use in Brazil during this expansionary period was much higher than in the United States.

Next, we calculate elasticities for the latter part of the 2000-09 period. Only contemporaneous elasticities are calculated because any land response to a two-year lag in response to the increase in expected returns observed in 2008 and 2009 have not yet occurred. We consider two periods in Figure 2: the contraction period during 2004-06 and the recent expansion period during 2006-09. The contemporaneous implied price elasticity during the contraction period is 0.382 which is 42% lower than the contemporaneous price elasticity between 1997-99 and 2001-03. The contemporaneous price elasticity is 0.477 during the recent

expansion period (2006-09), which is 28% lower than the contemporaneous price elasticity between 1997-99 and 2001-03. The decrease in cropland responsiveness to increased expected net returns in the recent period could reflect Brazil's attempts to a tougher regulation on converting forest into cropland. Other reasons that could be advanced for the reduced response are the high level of indebtedness after the Brazilian farm crisis of 2004-06 (Soares Damico and Nassar 2007), high transport costs, and lack of financing as a result of the recent credit crunch. To further investigate the source of land-use change, we include pasture land into the total land use.

Inclusion of pasture land provides us with additional information about land-use changes because with a fixed amount of total land in Brazil, an increase in cropland must correspond to a decrease in other land (pasture or forest). If the elasticity of crop plus pasture land is quite low or zero, then we can conclude that little or no forest land is converted in response to expansion of crops. If the elasticity is high, then we can conclude that the conversion of forest land is significant. However, there is no official time series database for pasture area in Brazil. We used Agricultural Census from the IBGE database for 1996 and 2006 for all regions, except for the Amazon, which is considered underestimated by Brazilian experts. The way to eliminate this problem was using satellite images for pasture area in the Amazon and the time series was based on the deforestation rate. Deforestation rate and cattle herd were also considered in order to calculate pasture area for the years from 2007 to 2009. For the other regions, time series for pasture area was calculated using Census data for 1996 and 2006 and distributed over time as a function of cattle herd. From 2007 to 2009, pasture area was calculated considering a yield trend (based on the past) and cattle herd database. To mitigate this problem, although pastureland during 2007-09 was likely decreasing, we hold pasture during this period constant and assume it

to be equal to the pastureland as of the year 2006. Table 18 shows that implied price elasticities of land use after including pastureland,<sup>5</sup> which range from 0.007 during the price decline period (2004-06) to 0.245 during the expansion period between 1997-99 and 2001-03 (two-year lag for land). Elasticities after including pasture are lower than those without the pastureland in every scenario. During the first expansion period, implied price elasticities with the pastureland decrease from 0.664 to 0.201 for the contemporaneous case and from 0.895 to 0.245 for the two-year lag for land case. That is, after including pastureland, the land change becomes less responsive to price than before. This is especially true during the recent land expansion between 2006 and 2009 in which the implied price elasticity drops from 0.447 to 0.082 after including pastureland. The decrease in elasticity implies that the majority of new cropland is converted from pastureland and only a small portion is converted from the forest. Note that the implied price elasticity of 0.082 is calculated by fixing pastureland as constant during 2007-09. Hence, elasticities would be smaller if the actual pastureland during this period were decreasing; that is, the amount of the forest converted into cropland and pastureland can also be smaller. If crop returns continue to be high in the future, then we would expect that the elasticity of cropland plus pastureland with a two-year lag would be somewhat higher than the contemporaneous elasticity reported in Table 18.

## **Conclusions**

This research provides estimates of the response of land use to recent large increases in crop returns. The land-use response, estimated using land-use elasticities with respect to expected returns and price, is crucial for researchers who attempt to determine the amount of land substitutability among forest, crops, and pasture as a result of biofuels expansion and climate

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<sup>5</sup> Since our goal is to analyze the possible land-use change from forest, not the competition between the cropland and the pastureland, for simplicity, expected net returns for pastureland are assumed to be equal to expected net returns for cropland.



change legislation. The recent run-up in expected net returns for crops gives us an excellent natural experiment to estimate land-use elasticities. In the United States, expected net returns increased sharply from crop year 2006 to 2009. At their peak in 2008, expected net returns were almost \$300/acre, more than double the average net returns in the past. During the same period, the area of the eight largest crops planted increased by 5 million acres, from 234 to 239 million acres. The sharp increase in expected net returns stems from the unprecedented increase in agricultural commodity prices over this period.

Using different periods and the elasticity of expected net returns with respect to expected price, which ranges from 1.038 to 1.432, the implied acreage elasticity with respect to expected price in Brazil ranges from 0.007 (between 2003-05 and 2007-09) to 0.029 (between 2007-09 trend to 2007-09 actual). The implied hectare price elasticities in Brazil are significantly higher than those of the United States. The price elasticities in Brazil range from 0.382 (between 2004 and 2006) to 0.895 (between 1997-99 and 2001-03 using a two-year lag for land). The higher elasticity of 0.895 reflects the period with land-use expansion while the lower elasticity of 0.387 reflects the period with land-use contraction. With the recent land expansion between 2006 and 2009, the implied price elasticity is 0.447. That the land elasticities are significantly higher in Brazil than in the United States comes as no surprise. However, Brazilian land hectare elasticities that include pastureland appear to be quite inelastic (ranging from 0.007 to 0.245). The lower elasticity after including the pastureland implies that the increase in cropland is mostly coming from pastureland as opposed to forestland, particularly in the recent period. This finding should help modelers better calibrate their land-use models in Brazil.

In the United States, even with a doubling of expected net returns from about \$130 (between 1995 and 2003) to \$299 in 2008, only 5 million more acres of crops were planted. Considering

this inelastic acreage supply, predictions that significant amounts of cropland will be converted to forestland at a modest CO<sub>2</sub> price of \$30 per metric ton (Brown et al. 2010) should be carefully analyzed.<sup>6</sup> In addition, whereas \$30 per metric ton may be attractive to farmers given the land rental rates assumed, the price increases resulting from cropland removal may render this value unattractive for afforestation. Finally, more research and discussion should be conducted to explore the policy implications of these estimates on the reliability of current estimates of land-use change from biofuels and climate change legislation.

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<sup>6</sup> Using the results of Brown et al., we calculate the elasticity of cropland to crop prices used to be approximately 0.24, which is higher than the one estimated here.

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**Table 1. Estimates of Pre-Planting Time and Harvest Time**

	Symbol	Estimated Pre-Planting Time	Harvest time		Exchange
			Future Contract		
<b>United States</b>					
Corn	C-	January	December		Chicago Board of Trade (CBOT)
Soybeans	S-	January	November		Chicago Board of Trade (CBOT)
Wheat	W-	January	July		Chicago Board of Trade (CBOT)
Upland Cotton	CT	January	December		Intercontinental Exchange (ICE)
Barley	WA	January	December		Winnipeg Commodity Exchange (WCE)
Oats	O-	January	July		Chicago Board of Trade
Rice	RR	January	November		Chicago Board of Trade (CBOT)
Canola	WC	January	November		Winnipeg Commodity Exchange (WCE)
<b>Brazil<sup>a</sup></b>					
Corn 1st crop	Est. by C-	September (T-1)	March (T)		Chicago Board of Trade (CBOT)
Soybeans	Est. by S-	September (T-1)	March (T)		Chicago Board of Trade (CBOT)
Cotton	Est. by CT	September (T-1)	March (T)		Intercontinental Exchange (ICE)
Rice	Est. by RR	September (T-1)	March (T)		Chicago Board of Trade (CBOT)
Sugarcane	Est. by sugar (SB)	September (T-1)	March (T)		Intercontinental Exchange (ICE)
Corn 2nd crop	Est. by C-	March (T)	July (T)		Chicago Board of Trade (CBOT)

<sup>a</sup> Wheat is excluded in this analysis. Although widely grown in the southern region of Brazil, wheat is a winter crop and is not likely to compete with other summer crops shown in the table.

**Table 2. Total Land Use in the United States (million acres)**

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	million acres														
Corn	71.5	79.2	79.5	80.2	77.4	79.6	75.7	78.9	78.6	80.9	81.8	78.3	93.5	86.0	86.5
Soybeans	62.5	64.2	70.0	72.0	73.7	74.3	74.1	74.0	73.4	75.2	72.0	75.5	64.7	75.7	77.5
Wheat	69.0	75.1	70.4	65.8	62.7	62.5	59.4	60.3	62.1	59.6	57.2	57.3	60.5	63.2	59.1
Upland Cotton	16.7	14.4	13.6	13.1	14.6	15.3	15.5	13.7	13.3	13.4	14.0	14.9	10.5	9.3	9.0
Barley	6.7	7.1	6.7	6.3	5.0	5.8	5.0	5.0	5.3	4.5	3.9	3.5	4.0	4.3	3.6
Oats	6.2	4.6	5.1	4.9	4.7	4.5	4.4	5.0	4.6	4.1	4.2	4.2	3.8	3.3	3.4
Rice	3.1	2.8	3.1	3.3	3.5	3.1	3.3	3.2	3.0	3.3	3.4	2.8	2.8	3.0	3.1
Canola	0.4	0.4	0.7	1.1	1.1	1.6	1.5	1.5	1.1	0.9	1.2	1.0	1.2	1.0	0.8
Double Crop	5.1	5.8	5.4	5.4	4.6	4.6	4.1	4.2	3.9	4.4	2.5	3.7	5.1	7.2	4.9
Total Acres <sup>a</sup>	246	259	258	258	255	258	252	253	253	251	248	246	249	253	250
% Total Acres	94%	93%	94%	94%	93%	94%	93%	94%	94%	95%	95%	95%	95%	94%	95%

Source: National Agricultural Statistics Service, USDA, online reports.

<sup>a</sup> To avoid double counting land used for double crops, the total double-crop acres are subtracted from total acres. Double-cropped acres are obtained from various years of FAPRI Outlook reports.

**Table 3. Total Land Use in Brazil (thousand hectares)**

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
	thousand hectares													
Corn 1st crop	11,585	9,042	9,807	9,855	10,542	9,563	9,678	9,470	9,002	9,632	9,421	9,636	9,271	8,281
Corn 2nd crop	2,214	2,349	2,706	2,903	2,430	2,735	3,548	3,313	3,206	3,332	4,634	5,130	4,901	4,901
Soybeans	11,381	13,158	12,995	13,623	13,970	16,386	18,474	21,375	23,301	22,749	20,687	21,313	21,743	23,063
Cotton	658	880	694	824	868	748	735	1,100	1,179	856	1,097	1,077	843	792
Rice	3,494	3,249	3,845	3,678	3,249	3,220	3,186	3,676	3,938	3,018	2,967	2,875	2,909	2,832
Sugarcane	4,880	5,050	4,976	4,880	5,023	5,206	5,378	5,634	5,816	6,180	6,964	8,211	8,568	8,574
Total Hectares	37,340	35,696	36,911	37,330	37,855	39,869	42,556	47,006	48,690	47,633	46,035	47,910	48,559	49,184
(excludes corn 2nd crop)														
% Hectares <sup>a</sup>	86%	88%	88%	88%	89%	88%	88%	88%	89%	89%	89%	90%	89%	89%
(excludes corn 2nd crop)														

Source: FAPRI, CONAB, IGBE and ICONE (Institute for International Trade Negotiations)

<sup>a</sup>Percentage of total land cropland in Brazil.



**Table 4. U.S. Basis**

Contract	Units	Basis	Averaging Period
Corn	\$/bu	0.05	1990-2008
Soybeans	\$/bu	0.09	1990-2008
Wheat	\$/bu	-0.04	1990-2008
Upland Cotton	\$/lb	0.02	1990-2008
Barley <sup>a</sup>	\$/bu <sup>b</sup>	-0.16	1997-2007
Oats	\$/bu	0.13	1990-2008
Rice	\$/cwt	0.13	1990-2008
Canola <sup>a</sup>	\$/lb <sup>c</sup>	0.01	1994-2008

<sup>a</sup> Barley and canola futures are quoted in Canadian dollars. To convert into US\$, we use the Canadian/USD futures (Symbol: CD) from the International Monetary Market (IMM). Canadian/USD futures have four contracts per year: March, June, September, and December. The harvest time for barley is in December. Hence, we use the average December Canadian/USD futures to obtain the exchange rate. However, the harvest time for canola is in November, which does not correspond to any Canadian/USD futures contracts. Therefore, we use the average of September and December contracts in order to calculate the exchange rate.

<sup>b</sup> Barley futures contracts are traded at Winnipeg Commodity Exchange (WCE). Each contract is quoted as Canadian dollar/ton. We use the conversion ratio 45.9 bushel/ton to convert into per bushel unit.

<sup>c</sup> Canola futures contracts are traded at Winnipeg Commodity Exchange (WCE). Each contract is quoted as Canadian dollar/ton. We use the conversion ratio 2205 lbs/ton to convert into per pound unit.

**Table 5. Expected Prices for the United States**

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Corn <sup>a</sup>	2.47	2.88	2.59	2.76	2.36	2.40	2.48	2.32	2.36	2.60	2.26	2.44	3.79	5.00	4.31
Soybeans	5.74	6.94	6.73	6.50	5.39	5.11	4.82	4.39	5.11	6.50	5.36	6.06	7.42	12.08	9.62
Wheat	3.47	4.37	3.53	3.52	3.02	2.84	3.09	3.02	3.16	3.91	3.18	3.59	4.87	8.48	6.17
Upland Cotton	0.72	0.75	0.74	0.70	0.61	0.57	0.59	0.40	0.56	0.66	0.48	0.57	0.57	0.75	0.52
Barley			2.33	2.41	2.01	2.03	2.11	2.21	2.43	2.53	2.32	2.65	2.88	4.80	3.02
Oats	1.19	2.11	1.45	1.45	1.02	1.02	1.07	1.50	1.72	1.46	1.38	1.63	2.62	3.27	2.22
Rice	7.01	8.69	9.24	9.36	8.45	6.87	6.01	4.76	5.55	8.19	7.11	9.24	11.14	14.57	14.52
Canola	0.12	0.12	0.12	0.11	0.09	0.08	0.08	0.08	0.10	0.11	0.09	0.10	0.14	0.24	0.16

<sup>a</sup>Units are as defined in Table 4.

**Table 6. Brazil Basis**

	Units	Basis	Averaging Period
Corn	R/ton		
Soybeans	R/ton	53.3	1998-2008
Cotton	R/ton	286.1	1996-2007
Rice	R/ton	122.4	1996-2008
Sugarcane	R/ton		

**Table 7. Brazil: Planting Time Quote of Harvest-Time Futures (Less Basis if Applicable, Year 2000 = 100)**

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Corn 1st crop	163	142	126	182	142	222	281	196	174	127	134	154	215	124
Soybeans	322	261	237	330	279	376	482	421	357	265	220	321	375	266
Cotton	484	495	569	598	644	458	677	832	505	312	278	250	216	164
Rice	280	303	312	275	225	212	232	368	338	204	272	258	465	275
Sugarcane	38	41	29	38	46	46	43	35	44	52	49	33	43	53
Corn 2nd crop	151	145	131	192	154	203	237	254	171	136	213	232	149	124

**Table 8. Loan Rate from Farm Bills**

	Units	1996 Farm Bill						2002 Farm Bill						2006 Farm Bill		
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Corn	\$/bu	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.98	1.98	1.95	1.95	1.95	1.95	1.95	1.95
Soybeans	\$/bu	5.26	5.26	5.26	5.26	5.26	5.26	5.26	5	5	5	5	5	5	5	5
Wheat	\$/bu	2.58	2.58	2.58	2.58	2.58	2.58	2.58	2.8	2.8	2.75	2.75	2.75	2.75	2.75	2.75
Upland Cotton	\$/lb	0.5192	0.5192	0.5192	0.5192	0.5192	0.5192	0.5192	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Barley	\$/bu	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.88	1.88	1.85	1.85	1.85	1.85	1.85	1.85
Oats	\$/bu	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.35	1.35	1.33	1.33	1.33	1.33	1.33	1.33
Rice	\$/cwt	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Canola	\$/lb	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.096	0.096	0.097	0.097	0.097	0.097	0.093	0.093

**Table 9. LDP Price Gap**

	Units	LDP Price Gap Average between 1998 -2004	% of Average Futures Price
Corn	\$/bu	0.26	9%
Upland Cotton	\$/lb	0.0757	12%
Oats	\$/bu	0.23	14%
Rice	\$/cwt	2.01	23%
Soybeans	\$/bu	0.56	9%
Wheat	\$/bu	0.48	12%
Barley	\$/bu	0.78	30%
Canola <sup>a</sup>	\$/lb	0.01	9%

<sup>a</sup>The LDP price gap is not available for canola. We approximate the LDP price gap for canola using the same % of average futures price from corn and multiply with the average futures price from canola in Table 5. That is, we use  $9\% * 0.12 = 0.01$ .

**Table 10. Implied Volatility of Options on Harvest-Time Futures Quoted During Planting Time**

	Volatility (%)															Avg. without 2009
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Corn	17	20	20	24	22	26	23	20	21	25	22	24	30	27	71	23
Soybeans	16	18	18	20	17	27	20	20	18	25	24	25	24	28	67	22
Wheat	17	22	21	23	25	28	25	23	27	30	25	25	26	36	54	25
Upland Cotton	16	16	14	12	17	18	16	24	18	19	24	21	19	22	63	18
Barley	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Oats	22	28	36	24	36	27	27	33	30	29	25	25	26	28	28	28
Rice	20	20	20	20	20	20	18	20	20	20	26	19	16	20	46	20
Canola	15	15	20	20	20	20	20	21	20	18	24	23	23	22	41	20

<sup>a</sup> The implied volatility is mostly calculated at the beginning of the 2008 calendar year. Hence, to obtain the average implied volatility across time, we exclude the volatility during 2009 because of the financial turmoil. The inclusion of the 2009 volatility will exaggerate the average volatility.

<sup>b</sup> We only have the data for 2008 implied volatility for barley. Hence, we assume the same implied volatility for other years.

<sup>c</sup> We only have the data between 2005-2007 and 2009 implied volatility for rice. We assume that the volatility between 1995-2004 and 2008 is the same as the average volatility between 2005 and 2007.

**Table 11. Expected Marketing Loan Gains**

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Corn	0.04	0	0.03	0.01	0.09	0.09	0.06	0.14	0.12	0.05	0.16	0.09	0	0	0
Soybeans	0.21	0	0.00	0.01	0.46	0.74	1.00	1.17	0.48	0.00	0.31	0.04	0	0	0
Wheat	0.03	0	0.03	0.04	0.22	0.34	0.18	0.35	0.27	0.02	0.22	0.06	0	0	0
Upland Cotton	0.08	0.07	0.07	0.07	0.14	0.16	0.14	0.30	0.17	0.12	0.24	0.17	0.17	0.09	0.27
Barley	0.33	0.15	0.26	0.21	0.49	0.47	0.41	0.51	0.34	0.26	0.39	0.19	0.09	0	0.05
Oats	0.35	0.01	0.22	0.19	0.53	0.50	0.46	0.27	0.14	0.27	0.31	0.16	0	0	0.01
Rice	1.50	0.10	0.01	0	0.21	1.64	2.50	3.76	2.96	0.38	1.40	0.01	0	0	0
Canola	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.07	0.06	0.03	0.05



**Table 12. Expected Yield in the United States (per Acre)**

	Units	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Corn	bu	124	123	125	127	131	133	136	138	138	141	146	148	150	152	155
Soybeans	bu	38	38	38	39	40	40	40	40	41	40	41	42	42	43	43
Wheat	bu	37	37	37	37	39	40	40	41	40	41	41	42	42	42	42
Upland Cotton	lb	686	651	669	674	667	656	654	665	666	680	713	738	756	780	792
Barley	bu	56	57	58	59	59	60	61	61	60	60	62	63	64	64	64
Oats	bu	56	55	56	57	58	58	60	60	60	61	62	63	63	63	63
Rice	lb	6,052	6,018	6,121	6,144	6,105	6,116	6,211	6,331	6,445	6,556	6,704	6,768	6,866	6,998	7,056
Canola	lb	1,315	1,435	1,551	1,600	1,685	1,719	1,749	1,779	1,768	1,797	1,854	1,867	1,869	1,849	1,863

**Table 13. Weighted (Over Regions) Expected Yield in Brazil (per Hectare)**

	Units	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Corn 1st crop	mt <sup>a</sup>	2.62	2.74	2.84	2.89	3.12	3.11	3.19	3.28	3.43	3.57	3.65	3.77	3.83	3.80
Corn 2nd crop	mt	1.92	2.08	2.16	2.31	2.43	2.57	2.77	2.90	3.00	3.15	3.38	3.54	3.70	3.84
Soybeans	mt	2.33	2.37	2.39	2.42	2.45	2.48	2.52	2.56	2.59	2.62	2.62	2.67	2.70	2.73
Cotton	mt	1.31	1.78	1.98	1.99	2.43	2.58	2.75	2.93	3.13	3.36	3.65	3.91	4.14	4.37
Rice	mt	2.71	2.83	2.86	2.96	3.20	3.33	3.40	3.41	3.43	3.85	3.84	4.16	4.30	4.41
Sugarcane	mt	65.86	66.97	68.32	69.12	70.06	71.13	72.34	73.33	74.40	75.55	76.63	77.98	78.93	79.82

<sup>a</sup> mt = metric ton

**Table 14. Nominal Variable Costs in the United States (\$ per Acre)**

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Corn	162	164	162	161	160	168	165	149	164	179	188	208	231	303	333
Soybeans	78	82	81	81	78	79	84	75	80	84	92	95	107	131	145
Wheat	67	72	72	60	57	61	67	60	70	73	82	88	98	124	136
Upland Cotton	306	306	304	265	280	306	322	316	321	331	365	372	427	495	545
Barley	77	84	83	80	81	84	91	84	82	85	97	102	113	142	156
Oats	50	53	56	52	49	52	56	51	56	59	73	81	83	107	118
Rice	347	376	373	355	360	310	325	308	337	359	405	385	422	514	566
Canola	98	104	103	102	99	100	106	95	100	106	116	120	135	166	182

Source: FAPRI

**Table 15. Weighted (Over Regions) Variable Costs in Brazil (Real per Hectare) (Year 2000 = 100)**

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Corn 1st crop	208	203	222	286	320	287	316	394	380	411	399	457	479	439
Corn 2nd crop	126	164	157	119	227	175	306	343	275	379	295	346	348	358
Soybeans	264	292	315	402	421	367	395	429	428	486	511	461	538	528
Cotton	508	533	914	1,098	1,300	1,214	1,331	1,651	1,627	1,865	1,883	2,080	2,233	2,185
Rice	377	356	446	495	485	491	510	721	759	891	714	771	848	862
Sugarcane	1,476	1,588	1,674	1,681	1,821	2,015	2,155	2,082	1,977	2,044	2,032	1,996	2,065	2,085

Sources: CONAB, IBGE, FNP, IDEA, and ICONE.

**Table 16. Elasticity of Land Use, United States**

	2003-2005 to 2007-2009	2004-2006 to 2007-2009	2007-2009 Trend to 2007-2009 Actual
%Δ in Acreage	0.3%	0.8%	1.9%
%Δ in Expected Returns	56.1%	58.4%	69.5%
Acreage Elasticity w.r.t. Expected Returns	0.005	0.014	0.028
Expected Returns Elasticity w.r.t. Price	1.337	1.432	1.038
Implied Acreage Elasticity w.r.t. Expected Price	0.007	0.020	0.029

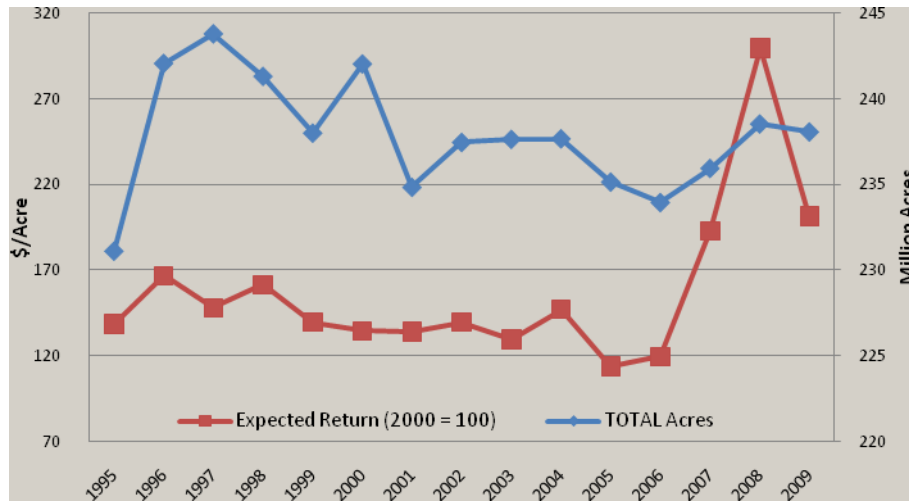
**Table 17. Elasticity of Land Use, Brazil**

	1997-1999 to 2001-2003	1997-1999 to 2001-2003 (2 year lag for land)	2004 to 2006	2006 to 2009
%Δ in Acreage	16.4%	22.1%	-5.0%	5.6%
%Δ in Expected Return	49.8%	49.8%	-30.8%	29.7%
Acreage Elasticity w.r.t. Expected Return	0.330	0.444	0.162	0.190
Expected Returns Elasticity w.r.t. Price	2.014	2.014	2.363	2.515
Implied Acreage Elasticity w.r.t Expected Price	0.664	0.895	0.382	0.477

**Table 18. Elasticity of Land Use Including Pasture Land, Brazil**

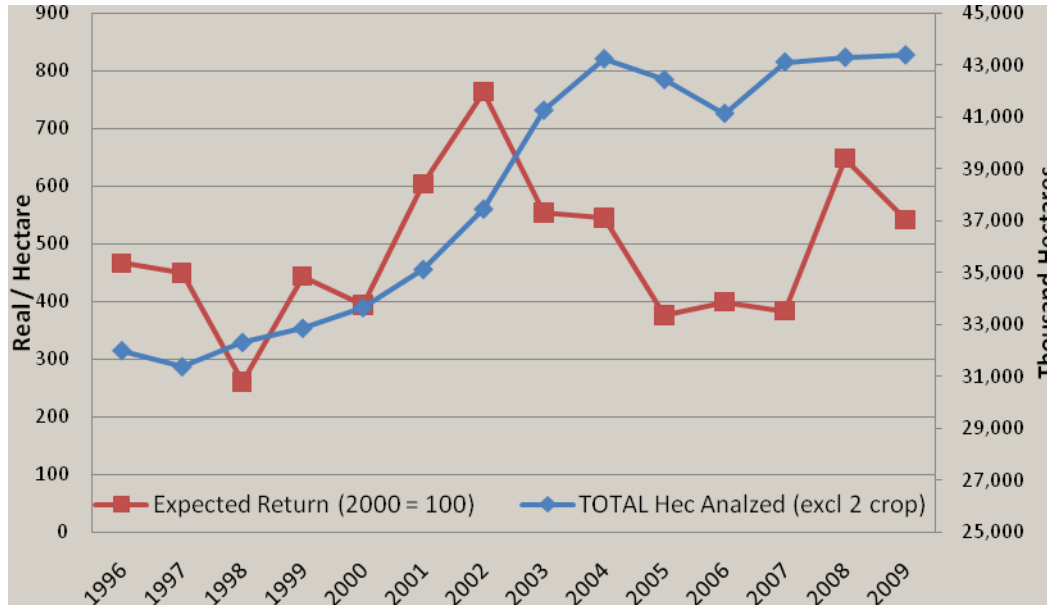
	1997-1999 To 2001-2003	1997-1999 to 2001-2003 (2 year lag for land)	2004 to 2006	2006 to 2009
%Δ in Acreage	5.0%	6.1%	-0.1%	1.0%
%Δ in Expected Return	49.8%	49.8%	-30.8%	29.7%
Acreage Elasticity w.r.t. Expected Return	0.100	0.122	0.003	0.033
Expected Returns Elasticity w.r.t. Price	2.014	2.014	2.363	2.515
Implied Acreage Elasticity w.r.t Expected Price	0.201	0.245	0.007	0.082

Figure 1. U.S. Land Use and Weighted Expected Net Returns (Year 2000 = 100)



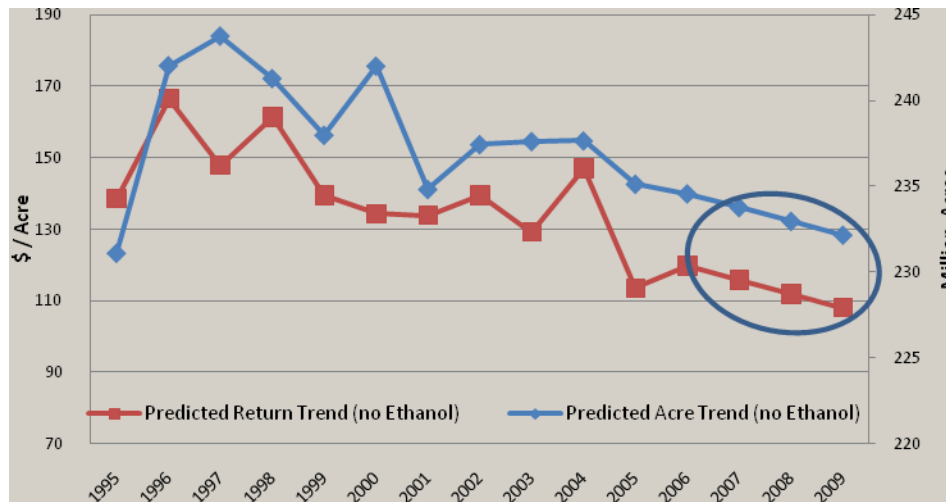


**Figure 2. Brazil Land Use and Weighted Expected Return (Year 2000 = 100)**



Note: Because of the unexpected high cost, expected net returns appear to be lower in 2007.

Figure 3. Projected U.S. Land Use and Expected Returns (Year 2000 = 100)



## APPENDIX

**Table A-1. Expected Return and Land Areas (Year 2000 = 100)**

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
<b>U.S.</b>															
Acres	231	242	244	241	238	242	235	237	238	238	235	234	236	239	238
Weighted															
Expected	139	167	148	161	139	134	134	140	129	147	113	119	193	299	201
Return															
<b>Brazil</b>															
Hectares		32,000	31,379	32,317	32,859	33,652	35,123	37,450	41,255	43,235	42,434	41,135	43,112	43,189	43,518
Weighted															
Expected		466	450	261	444	394	604	764	554	545	376	400	384	645	539
Return															